DESIGNING AN INTELLIGENT GREENHOUSE MONITORING SYSTEM BASED ON THE INTERNET OF THINGS

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Abstract. With the development of the Internet, the development of the Internet of Things (IoT) has also been promoted. The IoT is a network of "objects and objects connected." The IoT is based on cloud computing platforms and wireless networks. It acquires data based on sensor groups and conducts decision analysis to change the behavior control and feedback of objects, such as the greenhouse monitoring system studied in this paper. The IoT has subverted the traditional agricultural production model, from the agricultural farming model to the "smart agriculture" production-operation-sales model, which provides a direction for the sustainable development of agriculture in China at this stage. Based on the IoT and Zig Bee wireless sensor network technology, this paper designs a general scheme of an intelligent greenhouse control system based on IoT technology. The greenhouse control strategy was studied using IoT technology and fuzzy adaptive PID control algorithm. The experimental simulation was carried out with MATLAB software. The simulation results show that the optimal control of greenhouse temperature is achieved. The temperature in the greenhouse is always maintained at 16.5 °C -23.0 °C, and the humidity value is always maintained at 68.2% RH-89.3% RH. The test verified that the paper can achieve the expected effect for the greenhouse.
Keywords: *cloud computing platforms, smart agriculture, fuzzy adaptive PID, Zig Bee, MATLAB software*

Introduction

The Internet of Things (IoT) is a new technology that connects every object in a system to make it a whole. Integrating IoT technology into greenhouse control systems can make greenhouse monitoring systems more intelligent and coordinated. The main components of the IoT have the following parts. (1) Storage analysis (Buscheck et al., 2012; Zakeri and Syri, 2015; Dickinson et al., 2017; Patle et al., 2019), the server can receive and display the collected data in real time, and give corresponding processing analysis according to different application environments to achieve effective decision-making. (2) Network transmission (Wertheim et al., 2014; Hale et al., 2016; Choudhari et al., 2018), in order to achieve remote operation of the IoT, the collected information must pass through the sensor gateway and then transmitted to the remote server. (3) Information collection (Timonen et al., 2014; Joseph et al., 2019), in the monitoring area, we should deploy a variety of sensors to collect different data information in the environment, and send data through the transmitting device to form a wireless network. (4) Intelligent control (Kazmierkowski, 2014; Yoh-Han et al., 2016; Li et al., 2017; Jurkowski et al., 2015) combines its module with other controllers to achieve system control. After receiving the sent control command, different submodules will cooperate with each other. (5) Environment (Yahya et al., 2018), the collection and transmission of information is usually done through the environment, first of all, to perceive the

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surrounding environment, and then adjust the information through the corresponding control equipment. IoT technology is the product of the development of new generation information technology, and has been highly valued and widely used in wireless communication applications.

The IoT is generally combined with Zig Bee wireless sensor network technology (Espinosafaller, 2012), which is a short-range, low-rate wireless communication technology. The name of Zig Bee comes from the body language of the bees. When the bees find pollen, they will dance in a zig-zag motion. Through this splay, the message of the pollen's position and distance will be transmitted to the companion. It was formerly known as "Home RF Lite" or "Fire Fly" communication technology for wireless communication at close range (Yusof et al., 2015; Hithnawi et al., 2016; Tianlei, 2019). Zig Bee has the characteristics of small size, low energy consumption, short delay, large network capacity and strong stability. It can be easily integrated into various devices and is suitable for various intelligent control areas (Zheng et al., 2018). Zig Bee's network/security layer is responsible for providing LG WPAN with Zig Bee wireless network formation, network protection and information management services, and defines some common application function interfaces, defining appropriate service interfaces for the application layer to ensure stable operation of the MAC layer (Messo et al., 2013; Jang et al., 2015; Kasim et al., 2019). The application framework layer mainly contains application support layers, Zig Bee device objects, objects provided by the manufacturer, and is used to provide some common application framework models for Zig Bee applications (Fan et al., 2011; Nkwuda et al., 2019). Based on the IoT architecture, Zig Bee wireless sensor network technology has been applied to the greenhouse.

The greenhouse is also called glasshouse. Its main function is to plant crops and to maintain the function of heat preservation and light transmission. In the spring and winter seasons, there are some crops that are not suitable for growing. The greenhouse can artificially provide a growing environment for crops, which in turn increases crop yields. The variety of greenhouses can be divided into many different types depending on the roofing materials, lighting supplies, appearance and heating conditions. From the structure of the greenhouse, it should be a confined space and able to maintain temperature, while also having the function of facilitating ventilation and reducing temperature. Today's modern greenhouses use the computer control system to achieve intelligent control of environmental factors in the greenhouse, which improves the growth environment for crop growth. The greenhouse mainly uses sunshade materials to build some or all of the outer shells, and can build corresponding greenhouses for their crops in cold seasons or in climates where crop growth is not suitable (Messelink, 2014; Snipen, 2015; Azeem et al., 2018).

The main factors affecting the growth and development of crops are: temperature, moisture, light, air, biological factors, etc. (Vakilian and Massah, 2017). These factors do not exist alone, but have a close relationship with each other. The growth of crops is often affected by environmental integration. Crop growth is often affected by complex environments. Among them, factors such as temperature and humidity are the most important, and the stability of the greenhouse ecological environment is maintained by controlling them to maintain the environment in which crops are suitable for growth.

Based on the IoT architecture and Zig Bee wireless sensor network technology (Zhang et al., 2018a; Okpoli, 2019), this paper designs a general scheme of intelligent greenhouse control system based on IoT technology. The application of IoT technology

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and fuzzy adaptive PID control algorithm combined with greenhouses to analyze the characteristics of greenhouse environmental factors. Just as the above mentioned temperature, moisture, illumination, etc. were verified, the main control parameters in the greenhouse environment were determined. According to the control characteristics of the main factors, the control schemes of various environmental factors in the greenhouse were designed, and the corresponding mathematical models were established. The greenhouse temperature control strategy was studied (Zhang et al., 2018b; Sunny et al., 2018). The experimental test verified that the system design can achieve the expected effect of the greenhouse. Then, based on the characteristics of non-linearity and large hysteresis of greenhouse temperature, a fuzzy adaptive PID controller is designed. According to the actual requirements of greenhouse temperature, the PID parameters are adjusted online to achieve optimal control of greenhouse temperature (Zou, 2018). The simulation results show that the algorithm has good effectiveness in the temperature control process.

Proposed method

Fuzzy PID control algorithm

The greenhouse monitoring system is a group of 15 greenhouses and a complex monitoring system for monitoring the environment. In terms of monitoring, there are mainly indoor temperature, humidity and light. It is also necessary to monitor the multi-parameter complex data such as moisture, pH and even air content in the soil, temperature and humidity of plant foliage. In the control, there are many devices such as fans, heating pipes, sunshades and humidifiers, which need to participate in the environmental change process of the greenhouse.

The fuzzy PID control algorithm can adjust the scale factor, integral factor and differential factor of the conventional PID control in real time according to the pre-designed fuzzy rules to adjust the environmental parameters of the greenhouse. The main core is the PID control method, and the fuzzy control is the method of continuously adjusting the PID parameters.

In practical engineering applications, the most commonly used controller design is the PID controller. It is mainly composed of the proportional coefficient k_p, the integral coefficient k_i and the differential coefficient k_d. The structure of the fuzzy PID controller is shown in *Figure 1*.

Among them, $r(t)$ is the set value of the system, $y(t)$ is the actual measured value of the system, $e(t)$ is the difference between the system set value and the measured value of the system, that is, the deviation, which is generally used as the input of the PID controller, and its calculation formula (*Eq. 1*) is:

$$e(t) = r(t) - y(t) \tag{Eq.1}$$

The output expression of the PID controller (*Eq. 2*) is:

$$u(t) = K_p e(t) + K_I \int_0^t e(\tau) dx + K_D \frac{de(t)}{dt} \tag{Eq.2}$$

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In the above formula, K_P represents the proportional gain, K_I represents the integral gain, and K_D represents the differential gain. The PID controller adjusts the size of these three parameters to meet the requirements of the control system. According to the fuzzy control process, the precise quantity is transformed into the membership function of the fuzzy set by means of quantization and fuzzification. Fuzzification, by definition, converts the input space of the input domain observation into a mapping in the fuzzy set, essentially finding the fuzzy set membership function of the numerical domain corresponding to the concept.

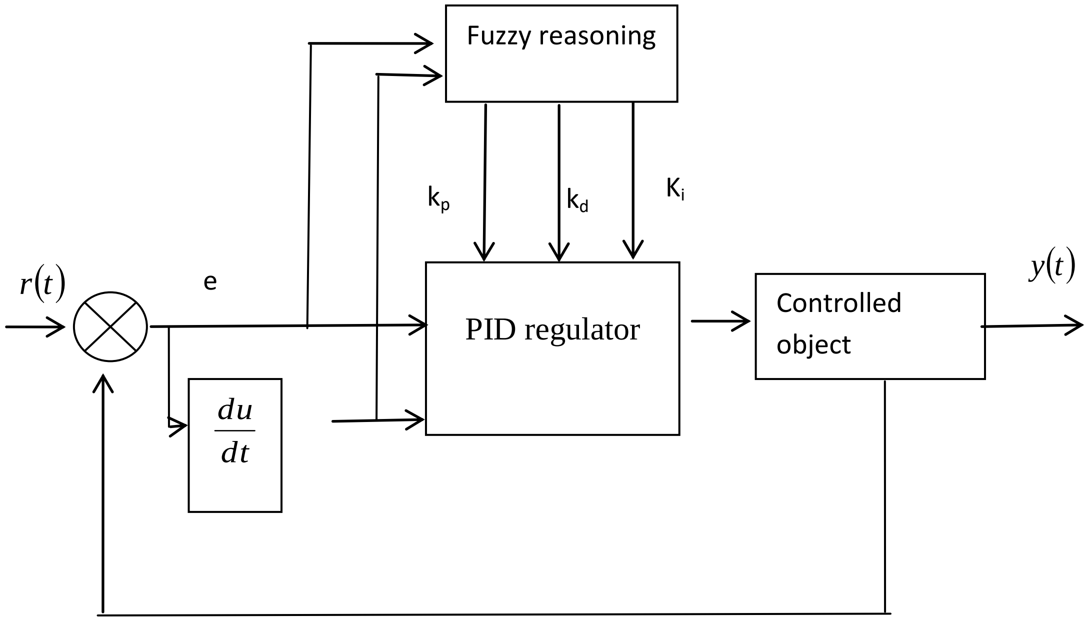

Figure 1. *Fuzzy PID structure diagram*

The tuning of PID parameters must consider the role and mutual influence of proportional integral differential coefficients in different corresponding stages. The traditional PID parameter adjustment experience shows that:

(1) When the deviation is large, a larger proportional coefficient should be taken to ensure the acceleration response speed of the system; in order to avoid the differential saturation caused by excessive deviation change, the control effect is out of range, and the differential coefficient change should be made smaller; The system response is over-adjusted, resulting in integral saturation, and the integral action should be removed;

(2) When the deviation and deviation change rate are medium, take a small proportional coefficient to prevent overshoot, and the integral differential coefficient should take the median value;

(3) When the deviation is small, a smaller proportional coefficient should be taken to ensure that no overshoot is generated, and a larger integral coefficient is taken to improve the dynamic characteristics of the system. The differential coefficient becomes smaller when the rate of change of the deviation is large, and becomes larger when the rate of change of the deviation is small.

(4) When the rate of change of the deviation is large, the smaller the proportional coefficient, the slower the response speed, and the greater the integral strain.

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Radial basis function (RBF) neural network data fusion

RBF network belongs to a multilayer forward network. When the BP network is used for function approximation, the weight is adjusted by the negative gradient descent method. This method of adjusting the weight has the disadvantages of slow convergence and local minimum. Since the BP neural network corrects the weight by the gradient descent method in the process of function approximation, this correction method has a slow convergence speed and easily converges to the local minimum point, which has certain limitations. RBF neural networks are superior to BP neural networks in terms of approximation ability, classification ability and learning speed.

The most commonly used RBF is a Gaussian function with two adjustable parameters, the center position and the variance b (the width parameter of the function). When using such a function, there are three sets of tunable parameters (parameters to be trained) of the entire network, that is, the center position, variance, and weight of the output unit of each basis function. Usually, the number of nodes in the hidden layer is selected as the number of training samples, and each node has a center vector of a RBF, which is the input vector of the training sample. Its network structure is shown in *Figure 2*.

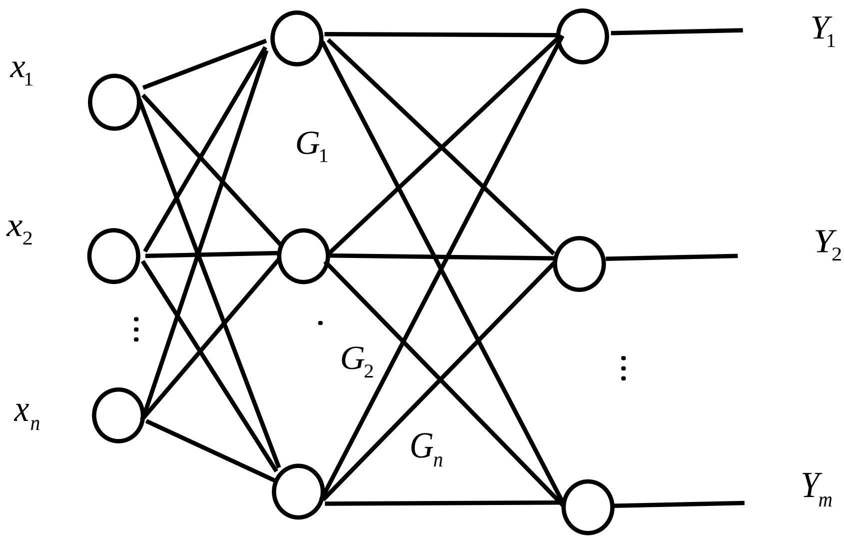

Figure 2. *RBF neural network structure*

The transfer function of the hidden layer node is Gauss function: f(x) = exp(-x^2/b) = exp(-δ^2K/b), where the parameter *b* controls the effect of the width of the bell-shaped Gaussian curve.

The center value of the Gaussian function of each hidden layer node is $C_K = |C_{K1}, C_{K2}, ..., C_{Kn}|$, $K = 1,2,...N$, and the net input of the hidden node is defined as the Euclidean distance between the input ***X*** and the RBF center vector of the hidden node (*Eq. 3*), namely:

$$\delta_K = \|X - C_K\|^2 = \sum_{i=1}^{n} (x_i - C_{Ki})^2 \quad K = 1,2,...N \qquad \text{(Eq.3)}$$

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The output $y_K = f(\delta_K)$ of the hidden layer node represents the extent to which the input mode leaves the center of the RBF represented by the implicit node. The final output layer of the network is a linear combination of the output of the hidden layer node. The output of the node j is: $Y_j = \sum_{K=1}^{N} w_{Kj} \cdot Z_K - \theta = W_j \cdot Z$, where $W_j = \lfloor w_{1j}, w_{2j}, \ldots, w_{Nj} \rfloor$ is the weight of the output layer and $Z = [z_1, z_2, ..., z_N]$ is the hidden layer output.

The learning process of the RBF network is divided into two phases. In the first stage, the center value C_k and the normalization constant of the Gaussian kernel function of each node of the hidden layer are determined according to all the input samples; in the second stage, the weight of the output layer is obtained by the least square method according to the sample.

In this paper, the RBF neural network model with soil temperature, humidity and soil moisture change per unit time as inputs can effectively predict soil moisture trends and deep soil water content.

Mathematical model of the controlled object

The greenhouse monitoring system is a complex system that comprehensively monitors environmental factor changes and enables the actuator to automatically adjust in real time to the required control algorithms.

In the environmental data monitored by greenhouses, the environmental factors required to monitor crops are multifaceted. The greenhouse group used in this paper consists of 20 large greenhouses. When the actuators act, the environmental parameters change slowly. The greenhouse monitoring system is a multi-parameter, time-varying, nonlinear and hysteresis system. When the system is large, it is inevitable that the external interference factors will increase. The influence of interference factors should be considered, and the parameters such as temperature and humidity, illumination and carbon dioxide that are easy to monitor are directly controlled. The parameters of the equipment that affect each parameter are changed in real time to achieve real-time balance, so that the internal environmental parameters of the greenhouse can promote the growth of plants. This project is a greenhouse group mainly planting peach trees. The growth of peach trees is mainly affected by temperature. Therefore, this chapter takes temperature as an example to illustrate, and other factors are referenced. According to the actual experience of the subject, taking temperature as an example, in the greenhouse temperature, the opening degree of the heating pipe plays the most important role in the temperature inside the greenhouse. At the same time, the plastic film in the greenhouse has the function of heat preservation and heat insulation, and the greenhouse will exhibit convective heat transfer characteristics when the heat changes, and when the temperature changes in a greenhouse, the plastic film has a function of heat storage. When the set temperature value becomes lower and the valve opening degree of the heating pipe is decreased, the hysteresis of slow heat dissipation is exhibited. Because of the large area of the greenhouse, it shows a certain inertia, so it includes the inertia lagging link. Therefore, the transfer function G(s) of the controlled object of the temperature control system of the greenhouse is defined (*Eq. 4*) as the following form:

$$G_{(S)} = \frac{Ke^{-\tau s}}{Ts+1} \qquad \text{(Eq.4)}$$

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The characteristics of the controlled object can be described by three parameters: K (static gain), τ (lag time), and T (time constant).

The static gain K refers to the ratio of the system output to the system input when the system reaches a steady state. It does not change due to other changes. It is only related to the controlled object and is a sign indicating the stability of the controlled object. The larger the K, the worse the stability, and the smaller the K, the stronger the stability.

The lag time τ represents a dynamic parameter describing the hysteresis, and it takes a long time for the controlled quantity to change as the input variable changes.

The time constant T reflects the degree of change of the output variable from the initial state to the steady state after the input signal is applied, reflecting the fast and slow characteristics of the dynamic process of the controlled object (Lu et al., 2019).

Discretization algorithm

The idea of discretization algorithm is to discretize continuous attributes into classification attributes, which provides an important way for the conversion between different types of data. In practical applications, the data set to be clustered contains both continuous attribute data and classification attribute data. But unfortunately, most of the existing algorithms can only process the data of the classification attribute, or the data of the classification attribute is more suitable than the data of the continuous attribute. In order to adapt to this situation, it is required to discretize the data of continuous attributes.

There are many advantages to the discretization of continuous attributes: discretization results reduce the need for storage space in subsequent processing algorithms; discretized data is the specification and simplification of the original data, easier to understand and use; continuous attribute discretization method can be effective to improve the accuracy of data analysis, thus enhancing the robustness to data noise.

Discretization of continuous attributes is a process of transforming quantitative data into qualitative data (Deng, 2019). Firstly, several segmentation points are set in the range of the continuous attribute, then the range of the continuous attribute is divided into discrete intervals, each sub-interval corresponds to a discrete value, and finally the original data is updated to a discrete value. The discretization problem is described as follows:

A decision table is a knowledge expression system consisting of a quad $S=(U,A,V,f)$, where $U=\{x_1,x_2,...,x_n\}$ is the domain and $A=C\bigcup\{d\}$ is the property set. $C=\{a_1,a_2,...,a_m\}$ and $\{d\}$ are the condition attribute set and the decision attribute set respectively, and $C\bigcap\{d\}=\Phi$, V is a set of attribute value ranges, and f is a map of $U\times A\rightarrow V$, which represents the value of each object in U on each attribute.

Suppose that for a conditional attribute $a\in C$ and a value field of $V_a=[l_a,r_a]$, where there is a set of points $l_a=c_0^a<c_1^a<c_2^a<...c_{ka}^a<c_{ka+1}^a=r_a$, then this set of points divides the conditional attribute range into: $V_a=[c_0^a,c_1^a)\bigcup[c_1^a,c_2^a)\bigcup....\bigcup[c_{ka}^a,c_{ka+1}^a)$. Here each $[c_i^a,c_{i+1}^a)$ is called an interval, each c_{ka}^a is called a breakpoint, and the set of all breakpoints on the attribute ***a*** constitutes a breakpoint set $Q^a=\{c_{ka}^a\}(I\le k\le m)$ of the attribute a. The ultimate goal of discretization is to find a suitable set Q of breakpoints

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for all continuous properties. Therefore, $Q = \bigcup Q^a (a \in C)$ defines a new decision table $S^p = (U, A, V^p, f^p)$, and for $\vee x \in U$, $i \in \{0,...k_a\}$, $f^p(x,a) = i \leftrightarrow f(x,a) \in [c_i^a, c_{i+1}^a]$.

The process of discretization of continuous attributes is the process of dividing the range of continuous attributes by using the selected breakpoints. Suppose that an attribute has r attribute values, and then there are $r-1$ breakpoints on this attribute. As the number of attribute values increases, the number of breakable points will increase with the value of the attribute. The process of selecting breakpoints is the process of merging attribute values. The discretization process of continuous attributes can reduce information redundancy and reduce the size of data, thus reducing the requirement for storage space. The discretization of the data can also reduce the complexity of subsequent processing data.

Evaluating the success of a discretization algorithm can be considered from the following three aspects: (1) The completeness of discretization. A successful discretization algorithm needs to be able to discretize multiple continuous attributes because the data set may contain more than one continuous attribute, so the discretization algorithm must be able to handle all of the continuous attributes in the data set rather than selectively processing some of the continuous attributes. (2) The degree of simplicity of discretization results. The number of discretized intervals should be as small as possible. If the number of breakpoints is too large, the recurrence of the data processed by the subsequent algorithm will be increased. (3) The degree of consistency of the data. Discretized results should maintain the original data as much as possible, minimizing the rate of information loss.

Experiments

After completing the software design of the greenhouse remote intelligent control system, the corresponding system debugging is carried out. The successful PC software interface is connected with the corresponding hardware device to test each control function module in the greenhouse to verify the feasibility of the overall system design. This article uses a PC with Windows 10 operating system as the host, and the target is the Tiny6410 development board. Firstly, you need to install the VMware10.0 virtual machine on your PC and then install your own Linux system in the virtual machine. Network training and simulation were carried out using the MATLAB software in the computer to control the temperature, moisture, the concentration of CO_2 and illumination intensity in the greenhouse environment. Compare the data collected by the smart system sensor with the data measured by the humidity meter (Yi, 2018).

Discussion

This paper gives an overall framework considering the limitations of current equipment, the structure of the greenhouse site, and the needs of reality. The greenhouse site is mainly composed of data collection and video surveillance; the server is composed of a data server, a video server and a server, and the three can be on the same server; the client actually refers to the customer and the agricultural monitoring service network that is open to the public (Zeng, 2018). The greenhouse site is connected to the server through a mobile network, and the client and server interact through the Internet, as shown in *Figure 3*.

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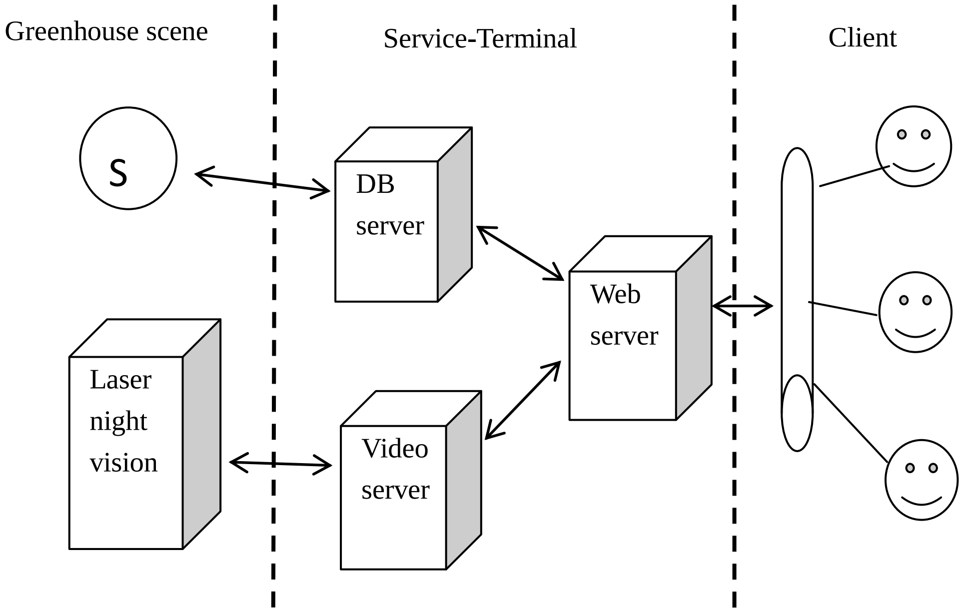

Figure 3. *Overall system framework*

The main environmental factors affecting crop growth in the microclimate environment of greenhouses are temperature, humidity, solar radiation, and carbon dioxide concentration (Shan, 2018). This test mainly collected detailed test parameter values for meteorological conditions such as temperature, humidity, CO_2 concentration and illumination intensity in the greenhouse. Among them, a routing node is set up between each module, which can be regarded as a “data transmission transfer station”. When the distance between the module and the coordinator is far, this may result in no way to transmit data. At this time, the routing node plays a role of relaying, providing convenient data transmission channels through the node to ensure the integrity of system data transmission. Therefore, the setting of the node not only ensures the stability of the system control process, but also increases the transmission distance of the data (Zhang et al., 2017).

In order to verify the feasibility of the system, when collecting data on the greenhouse environmental factors, before the experiment, taking into account the accuracy of the reference values, it is necessary to accurately test each sensor module. Various types of sensors are installed in different corners of the laboratory to ensure the integrity of data collection anywhere in the laboratory. When detecting the received data, in order to more intuitively observe the trend of the data, one of the sensors collects the data interface, and the detected value obtained by the interface is compared with the data collected by the actual engineering instrument, thereby verify the validity of the data collection (Lu, 2018). During the interval of every half hour, data of 6 groups of different time periods are collected, and the collected data is detected, and the average value of the data is compared with the actual collected data. The data comparison results are shown in *Tables 1* and *2*.

According to the experimental data comparison analysis table, it can be seen that the temperature sensor used in the laboratory has a temperature error range of ± 0.3 °C compared with the industrial meter, and the humidity sensor used in the laboratory has a humidity error range of -0.6–1.1% RH compared to the industrial instrument. Through

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the comparison of experimental data, the temperature and humidity sensor measurement error is within a reasonable range, and the data collected by the sensor can be verified to have reliability characteristics.

Table 1. *Comparison of light intensity data*

Serial number	Temperature collected by the sensor °C	Temperature measured by the temperature meter °C	Temperature error value °C
1	17.6	17.7	-0.1
2	19.2	19.1	0.1
3	20.4	20.6	-0.2
4	21.7	21.5	0.2
5	21.7	21.9	-0.2
6	23.2	22.9	0.3

Table 2. *Comparison of humidity data*

Serial number	Humidity collected by the sensor %RH	Humidity measured by humidity meter %RH	Humidity error value %RH
1	41.1	40.4	0.7
2	49.1	48.6	0.5
3	56.8	55.7	1.1
4	68.4	67.8	0.6
5	70.3	71.1	-0.8
6	76.5	77.2	-0.7

For the design of the illumination sensor, an LED light device is used to measure the light intensity in the laboratory. Six sets of data were taken for analysis. The average of the six sets of data was compared with the data collected by the light intensity measuring instrument in the actual project. The results of the comparative analysis of the light intensity data are shown in *Table 3*.

Table 3. *Comparison of light intensity data*

Serial number	Light intensity collected by the sensor Lx	Data measured by the illuminometer Lx	Error Lx	Relative error %
1	1103	1099	4	0.36
2	1356	1321	35	2.58
3	2689	2660	29	1.72
4	4780	4705	75	1.57
5	6643	6556	87	1.31
6	12453	12343	110	0.88

From the comparison of the above experimental data, it can be seen that the light intensity data collected by the sensors in the laboratory is between 0.36 and 2.58% than the light intensity of the actual engineering light intensity equipment. Therefore, the effectiveness of the data collected by this sensor is indicated.

Similarly, the CO_2 data will also be valid, so the data acquisition is available, and then the experimental results of the fuzzy adaptive PID controller are tested experimentally, and the pre-designed control system is applied to the greenhouse for experiments. In the aspect of temperature and humidity control, the fuzzy adaptive PID control method is introduced. Since the humidity and temperature control design are similar, the temperature is taken as an example for detailed design, and the illumination is controlled by the upper and lower limit values.

For the regulation of temperature and humidity in the greenhouse, a half-year follow-up test was conducted, and the test time was 08:30-15:00 every day. Through the parameter setting module in the system, the crop is set to a temperature range of 19 to 23 °C and a humidity range of 60–90% RH. According to its variation in the growth cycle, the ideal temperature setting is 20 °C, and the ideal humidity setting is 80% RH. In the parameter setting module, the value of the greenhouse degree is determined, and the value is input into the system, and after the corresponding saving process is performed, the intelligent control module is operated. In the one-week tracking test, the data collection interval is 30 min. The data collected on any day is selected for experimental analysis. The changes in greenhouse environmental factor parameter values are shown in *Table 4*.

Table 4. *Indoor environmental parameter values*

Serial number	Time	Temperature value °C	Humidity value %RH	Sunlight illumination lx	CO_2 concentration ppm
1	8:30	19.0	82.3	4312	1312
2	9:00	19.5	82.1	4641	1411
3	9:30	20.1	79.8	5123	1091
4	10:00	20.4	77.2	6001	901
5	10:30	20.7	78.8	9137	721
6	11:00	20.8	76.9	10011	901
7	11:30	21.2	77.8	12404	1047
8	12:00	21.5	80.9	13115	1109
9	12:30	22.1	82.6	10132	1216
10	13:00	23.0	79.3	11478	1110
11	13:30	22.4	77.8	10014	1921
12	14:00	21.1	76.9	9311	1104
13	14:30	20.1	80.2	8121	1114
14	15:00	19.5	83.1	7123	1220

It can be seen from *Table 4* that the temperature value in the greenhouse is always within the range of 16.5-23.0 °C in different time periods, and the humidity value is always kept within the range of 68.2–89.3% RH. According to the data collected from the outdoor, the indoor and outdoor temperature and humidity are compared, and the indoor and outdoor temperature comparison results are shown in *Figure 4*.

The dotted line represents the outdoor temperature change, the solid line represents the indoor temperature, and the blue line represents the temperature set value of 20 °C. It can be seen from the analysis in *Figure 4* that the error range between the indoor temperature change trend and the set value can be kept within ± 4 °C, while the indoor

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temperature is affected by the outdoor temperature. The increase of the outdoor temperature causes the indoor temperature to increase. A sudden drop in the outdoor temperature causes a decrease in the indoor temperature.

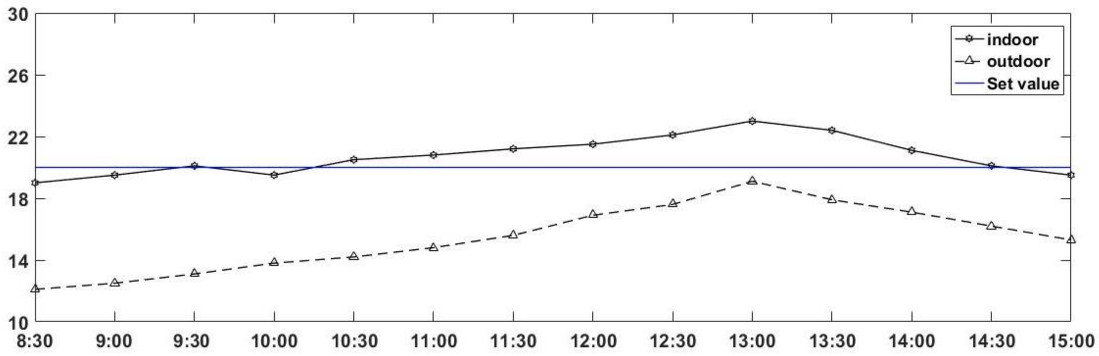

Figure 4. *Comparison of indoor and outdoor temperature*

The indoor humidity comparison results are shown in *Figure 5.*

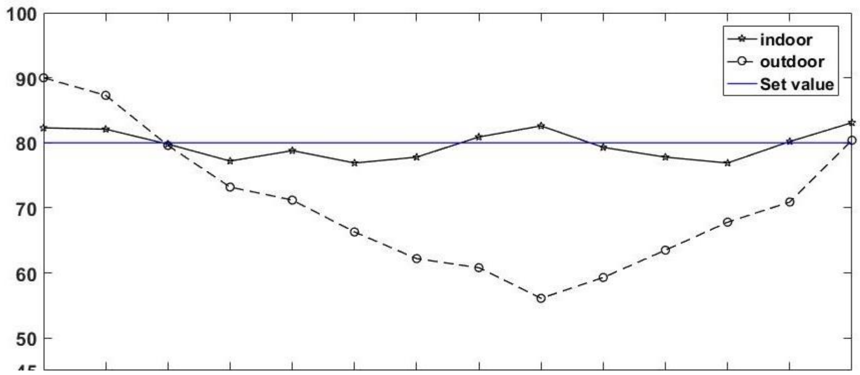

Figure 5. *Comparison of indoor and outdoor humidity*

The blue straight line is set to 80% R, the dotted line is the outdoor humidity, and the solid line is the indoor humidity. It can be seen from the analysis in *Figure 5* that the error range between the change of indoor humidity and the set value is kept at ± 10% RH, the error of humidity can be kept within the set ideal error range. The indoor temperature is increasing when the outdoor humidity is lowered.

Through the comparative analysis of the experimental data, the fuzzy adaptive PID control algorithm can respond to the environmental changes in the system in time, so that the environmental factor control process can have good performance indicators and meet the good control effect.

Conclusions

Greenhouse cultivation in agriculture has brought convenience to improve people's living standards, and has been rapidly promoted and applied. Environmental factors such as temperature, humidity, light intensity, and CO_2 concentration in the greenhouse

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planting environment have a great impact on crop production. Timely and effective monitoring of these environmental factors will greatly promote production. At the earliest, only the manual monitoring and control methods can be used for greenhouse environmental management. With the development of automation technology and computer technology, monitoring technology has gradually developed and is now applied to the IoT. In this regard, in the framework of the IoT, the Zig Bee node with sensors is placed in the greenhouse to collect data, and the required environmental data is collected in real time. The Zig Bee node self-organizes to form a wireless sensor network, which is passed through the Zig Bee node. Control information is passed to the controller of the actuator to control changes in environmental variables. It mainly monitors environmental parameters such as temperature, humidity, CO_2 concentration and light intensity in greenhouses, as well as remote control of water pump, exhaust, lighting and other equipment in the greenhouse. Finally, based on the characteristics of the greenhouse environment, the mathematical model of the greenhouse was established and the final model optimization was carried out. The mathematical model was established in MATLAB, and the performance of the designed controller was verified by simulation. The simulation experiments show that the fuzzy adaptive PID control algorithm is superior to the conventional PID control algorithm and pure fuzzy control algorithm in the dynamic performance index of system control, and is controlled by the following greenhouse cultivation.

Temperature and humidity control strategy

For example, in the low temperature environment in winter, the principle of controlling the temperature and then controlling the humidity should be followed. After the indoor temperature has reached a certain level, then the humidity is adjusted to meet the set requirements. If the humidity is high and the temperature is low, heating and heat preservation are the main factors. The dehumidification operation can only be achieved when the temperature rises to a specific value. In the summer when the temperature is high, the principle of controlling the humidity and then controlling the temperature should be followed. When the humidity is too low, you should turn on the humidifying device. When the temperature is too high, you need to measure the relative humidity in the room when you need to start the cooling device. The cooling device can only be started when the humidity value is less than a certain setting range.

Light intensity control strategy

The ideal value of the light intensity in the greenhouse is 20,000 to 70,000 lx. The specific implementation scheme is: (1) When the light intensity is greater than 70000 lx, open the outer shade net and close the inner shade net; (2) When the light intensity is between 20000 and 70,000 lx, if the external shading is turned off, the inner shading remains unchanged; if the external shading is turned on, the inner shading is turned off. (3) When the light intensity is less than 20000 lx, the inner and outer shade nets are closed; (4) When the light intensity is below 5000 lx and the time is between 8am and 17pm, turn on the fill light.

It can be seen that the Internet of Things will become a new “smart agriculture” production-operation-sales model, which is subversive to the traditional agricultural tillage. It is conducive to the sustainable development of agriculture in China at the present stage.

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